

# Appendix 6

## Solid and Liquid Residue Management Concept Design Report

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**Australian Zirconia Limited**  
**Project No:120-02**

**DUBBO ZIRCONIA PROJECT**

**SOLID and LIQUID RESIDUE MANAGEMENT**

**DESIGN REPORT**

**June 2013**



**D E COOPER & ASSOCIATES PTY LTD**

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*CONSULTING GEOTECHNICAL ENGINEERS*

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## **1.0 BACKGROUND**

The Dubbo Zirconia Project (“the project”) will mine and treat ore taken from an open pit mine located near Toongi, approximately 25km south of Dubbo in central NSW. The project is owned by Australian Zirconia Limited, a wholly owned subsidiary of Alkane Resources Limited, an Australian company listed on the ASX.

Processing of the ore mined from the open pit will produce several waste streams including a solid residue and a large volume of process water (liquid residue) which, because of contained impurities, cannot be returned to the plant. The size of the ore body will require that the storage facilities be designed for a very long life. Staging of the development of the storages may be used to delay or spread the capital costs associated with the construction. A nominal design life of 20 years has been adopted for this study, although it is noted that there is sufficient ore reserves to sustain future operations (up to 80 years at production rate proposed).

The Solid Residue Storage Facility (SRSF) will consist of a series of cells which will be lined with a double layer of HDPE and fitted with a leak detection system.

While HDPE has been in use for many years as a lining for this type of cell, there are new products on the market which claim to offer equally low permeability (typically  $<10^{-11}$  m/s). In view of the very large areas and high capital cost involved, these new product will be thoroughly evaluated before a decision on the lining is taken. This comment applies equally to the lining of the LRSF cells as discussed below.

The SRSF will be a permanent facility. The outer slopes of the SRSF will be progressively rehabilitated over the life of the project, with the upper solid residue surfaces being covered at closure.

It is assumed that the excess process water, or liquid residue, will be evaporated in a number of purpose constructed cells known as the Liquid Residue Storage Facility (LRSF). Constructed over four (4) distinct areas, and as a series of tiered cells within each area, the individual cells of the LRSF will be lined with a single layer of HDPE (see comment on alternative liner types above). At the end of the mine life, the LRSF will be decommissioned. Once all of the remaining water has been either lost by evaporation or pumped to one or more of the cells, the layer of salt over the base of each cell will be removed by mechanical means and delivered to a permanent storage and encapsulated. The HDPE liners from the LRSF cells will either be recycled (if facilities are available) or disposed off site to an appropriately licenced landfill. More details of the methods proposed to manage the salt from the LRSF are provided in Section 7.

## **2.0 WASTE STREAMS AND MANAGEMENT PROPOSALS**

### **2.1 General**

The waste streams are produced by the processing plant following the treatment of the run-of-mine (ROM) ore to produce rare metal products of Zirconium, Niobium and Yttrium, and Rare Earth Element (REE) products. The nominal ROM ore throughput used in the DFS study is 1Mt/a.

Based on the current plant circuit, the wet weight of the solid residue (filter cake) will be approximately 2 Mt/a. The weight of the dry solids will be 1.3 Mt/a.

The volume of liquid residue (in effect saline water) to be produced by the plant during the multiple washing cycles is estimated to 2.4 Mm<sup>3</sup>/a. This water cannot be re-used in the process. The volume of water which has to be removed from the system has been significantly reduced by re-cycling the water within the plant. Evaporation will be used to “lose” the 2.4 Mm<sup>3</sup> of liquid residue.

**Drawing 120-12-100** gives a general site plan with the LRSF, the SRSF and the Salt Encapsulation Cells shown.

## 2.2 Solid Residue Storage

Although there have been limited volumes of the solid waste produced by the pilot plant, the indications are that the filter cake will leave the plant at a moisture content where the material can be handled as a semi dry solid.

Once at the storage area, the material will be dumped and spread in layers by a small dozer and compacted using the dozer or specialist compaction equipment. Details of the development of the SRSF are provided in Section 3.

## 2.3 Liquid Residue Storage

The large volume of liquid residue produced by the plant will have to be stored and then “lost” by evaporation. The typical evaporation area comprises a number of cells which act as storage and provides the surface necessary for evaporation to take place.

As the water is lost by evaporation, salts will precipitate and be left on the base of each cell. This layer of salts will be removed, along with the liners, for permanent disposal at the end of the mine life. The details of the development and operation of the LRSF are given in Sections 4 and 5.

## 3.0 SOLID RESIDUE MANAGEMENT

### 3.1 General Description

The solid residue, which is a combination of precipitates plus the lime and limestone used to raise the pH of the end product, will enter the filter station as a slurry and leave as a semi dry filter cake. The filter cake will exit the plant by conveyor and be discharged either into an elevated hopper or onto a covered loading area. The solid residue will be loaded into the trucks which are used to bring ore to the plant, and back hauled to the SRSF.

### 3.2 Physical Description of the Waste

The solid waste is a blend of waste streams from the process that has been neutralised with dry lime. The solids are fine with a P80 of below 75 µm.

The filter cake gives the physical appearance of a damp fine sand or clay. There is a small amount of water released when the filter cake is squeezed but the majority of the contained moisture appears to be chemically bonded with the finer particles.

Geotechnical testing of the residue has been carried out in the Perth laboratories of SGS. The following parameters were found:

**Atterberg Limits**

LL – 45

PL – 37

PI – 8

Linear Shrinkage – 3%

**Compaction Testing**MDD – 1.33 t/m<sup>3</sup>

OMC 33%

**Triaxial Testing**

Cohesion – 6 kPa

Phi – 39 degrees

The full test results are given in **Appendix A**.

**Table 3.1** below provides a summary of the chemical make-up of the residue.

**Table 3.1** Chemical composition of the Solid Residue

	Units	To SRSF
Ag	ppm	5
Al	%	4.595
As	ppm	38
Ba	ppm	180
Be	ppm	39
Ca	%	7.54
Cd	ppm	<2
Cr	ppm	13
Cu	ppm	11
Dy	ppm	80
Er	ppm	35
Eu	ppm	2.7
F	%	0.26
Gd	ppm	80
Hf	ppm	150
Hg	ppm	<0.05
K	%	2.46
La	ppm	690
Mg	%	0.04
Mn	%	0.065
Nb	ppm	520
Nd	ppm	395
Ni	ppm	4
P	%	0.03
Pb	ppm	145

**Table 3.1** Chemical composition of the Solid Residue (Cont'd)

	Units	To SRSF
Pr	ppm	125
Rb	ppm	730
S	ppm	53600
Se	ppm	9
Si	%	20.4
Sm	ppm	85
Sn	ppm	25
Sr	ppm	45
Ta	ppm	100
Tb	ppm	12.5
Th	mg/L	<0.1
Ti	%	0.035
U	ppm	11.5
V	ppm	<20
Yb	ppm	28
Zn	ppm	445
Zr	ppm	1900

### 3.3 Volume of Solid Residue

Based on the current plant circuit, there will be approximately 1.3 Mt of dry solid residue produced each year. At a compacted in situ dry density of 1.3 t/m<sup>3</sup>, the annual volume of the material in the storage facility will be around 1 Mm<sup>3</sup>.

### 3.4 Concept for the SRSF

The design of the storage is based on a cellular concept, where each cell can be filled and then closed and rehabilitated. In this way the overall area of solid waste which is exposed at any one time can be limited. This will make the management of rainfall runoff easier, and allow the cost of final closure to be spread over the life of the project.

The design of the SRSF, comprising three cells, is based on a 20 year mine life. The volume of the waste in the cells will be 20 Mm<sup>3</sup>. **Drawing 120-12-301** provides a GA of the SRSF cells.

The total area of the three cells will be approximately 108 ha. Cells A (31 ha) and B (24 ha) will have dimensions of approximately 500 m by 450 m. Cell C will be larger with an area of approximately 48 ha.

The final external side slopes of the stacked waste will be 1:3 (vertical:horizontal). The final combined upper surface area of the three cells will be approximately 81 ha.

The bases of the storage cells and the upstream faces of the Stage 1 embankments will be lined with a membrane. A double liner will be used, with a leak detection system in between the two liners. The upper liner will likely be HDPE, with the lower liner constructed from clay or HDPE.

There are several alternative lining materials available which will be considered at the final design stage including geomembranes with bentonite (geosynthetic clay liners or GCL's) and bitumen impregnated geomembranes. It is accepted that any liner used will provide for a permeability not exceeding  $1 \times 10^{-9}$  m/s over 900 mm (or equivalent).

The leak detection system will comprise a network of small diameter filter pipes embedded in a free draining coarse sand or gravel. Alternatively there are a number of proprietary synthetic products which can be used to separate the two liners and provide drainage. The pipes will be linked to an outfall pipe which will report to a sump for collection and recovery of seepage.

### 3.5 Site Selection

The proposed location for the SRSF cells is to the south east of the plant site and due west of the open pit. The site for the initial two cells is on elevated ground on the catchment divide between Cockabroo Creek and Wambangalang Creek.

The site for the third cell will be in the west facing valley immediately to the west of the first two cells. The catchment area of the valley (within the Wambangalang Creek catchment) will be limited by the presence of the first two cells.

The area backs onto the mine waste rock emplacement. The main haul road between open pit and the plant passes to the north of the site.

The foundation conditions are not critical to the overall design of the SRF cells as each cell will be fully lined with a double layer of HDPE. The foundations consist of a thin cover of silty topsoil underlain by decomposed rock which quickly becomes competent. There are no stability issues with the embankment foundations.

The groundwater in the area of the SRSF cells is approximately 15m to 20m below the surface and therefore will have no impact on embankment stability or the performance of the HDPE liners. In the unlikely event that there is seepage from the SRSF, the seepage would have to pass through the fractures in the foundation rock before encountering the groundwater.

### 3.6 Development of the SRSF Cells

Cell A will be developed initially, followed by Cell B and then Cell C. There is a cross-fall of approximately 20 m over the site from the south eastern corner to the north eastern corner of Cell A. The fall to the west is approximately 10 m.

The initial external embankments forming Cell A which will be constructed along the northern side of the area will be approximately 15 m high with the embankment tapering out to the natural surface at the western end and along the eastern side. There will be a low embankment along part of the southern side of the storage. The embankments will be constructed using earth fill borrowed from within the storage area. The embankments will have a crest width of 5 m and side slopes of 1:2 upstream and 1:3 downstream. **Drawing 120-12-303** shows a typical section through the SRSF cells.

Once the Stage 1 earthworks have been completed, the cells will be lined with a double layer of HDPE sheeting, or equivalent as discussed in Section 3.4. A drainage layer will be provided between each layer to allow any seepage through the upper layer (the layer most likely to be damaged during operations) to be captured and therefore detected. Both the lower and upper layers of HDPE (or equivalent lining) will be fully tested for leakage at the completion of construction.

The Cell A Stage 1 embankments will provide for approximately 12-18 months of storage. The embankments will then be progressively raised by 20 m as the level of the compacted filter cake is raised. Upstream construction will be used to minimise the volume of fill material required. **Drawing 120-12-304** provides a typical cross section through the cells.

Cell B lies to the south of Cell A. There is a fall of approximately 20 m from east to west. The Stage 1 embankments will be constructed along the northern, western and southern sides of the area forming a side valley storage. As the initial storage fills, the embankments will be progressively raised and extended until the northern and southern embankments link up with the western embankment of Cells A and B. The Stage 1 Cell B embankments will provide for up to 12 months storage.

Cell C will be developed to the west of Cells A and B. An initial embankment will close off the shallow valley to provide for up to 12 months storage. As with Cells A and B, Cell C will be lined with a double layer of HDPE with a leak detection system. The Stage 1 embankments will provide up to 12 months storage.

### 3.7 Control of Incident Rainfall

Although there will be no water released from the solid residue during the placement and compaction, incident rainfall must be managed to ensure that the embankments forming the storage cells do not overtop.

Several options were investigated. A simple overflow weir could be used, however the weir would have to be re-constructed at each embankment lift. The water passing over the weir would have to be channelled down the external embankment, potentially leading to erosion of the embankment. A weir could also allow fine particles from the residue exit the SRSF.

An internal drainage system has been investigated and has been adopted. The system will be similar to a decant tower in a normal tailings storage, however there will be no rock mound. The slotted concrete tower sections will be wrapped in a geomembrane. The vertical well will house an electro submersible pump. The pump, controlled by float switches, will remove the water from the well. The water will be pumped to one of the cells of the LRSF. Details of the well system are given on **Drawing 120-12-305**.

### 3.8 Residue Placement

The residue will be trucked and/or conveyed from the plant to the SRSF. Back loading of the trucks which deliver the ore to the plant is being considered. Cell A will be developed initially. Once dumped, a rubber tyred dozer will be used to push out and spread the material over the liner to provide a tipping face. The layers of residue will be progressively compacted. A small dozer will be used to spread the material and maintain access for the incoming trucks. A self propelled smooth drum compactor will be used to compact the residue to the required in situ density.

It is likely that the layer thickness of the placed material will be limited to less than 300 mm to ensure that the material can be compacted to at least 95% of the maximum density attainable at the in situ moisture content. This will ensure that the material will have a high strength allowing the outer side slopes to be formed at slopes of 1:3 (vertical:horizontal).

The upper or working surface of the stack (in each cell) will be shaped to allow incident rainfall to flow to a pre-cast concrete well in which electro submersible will be located. Water collected in the sump will be delivered to one of the cells of the LRSF.

Monitor bores will be installed around the storage to enable the early detection of changes in the level or quality of the groundwater.

### 3.9 Ongoing Embankment Construction

Once the Stage 1 of the Cell A storage area has been filled, the outer embankments will be extended and progressively raised in 2 m lifts using upstream construction. In this form of construction, the borrowed earth fill used to construct the embankment lifts will be partly supported on the existing embankments and partly on the placed and compacted residue. The most important factor to be considered in designing an upstream embankment is the competency of the residue, as the material is normally discharged into the storage as a slurry. In the case of the Dubbo Zirconia Project, the solid waste material will be delivered as a near dry filter cake and will be compacted to form a strong mass.

While no stability analyses have been carried out to this time, the strength of the compacted residue ( $\phi = 39$  degrees), together with the use of competent fill material and the 1:3 overall outer slope, will ensure the stability of the stack. It is likely that added protection to the outer faces of the stack, in the form of a cover of competent rock, will be used to provide long term erosion protection. Drainage channels on the benches of the outer faces will be used to control surface runoff and therefore prevent erosion.

In the case of the SRSF cells, the residue directly upstream of the embankments will be competent compacted and unsaturated material easily able to support the earth fill embankment lifts. A detailed stability analysis will be carried out at the final design stage to demonstrate that under all expected loading conditions, the embankments will remain stable with a high factor of safety against failure.

Borrow areas for the winning of the embankment fill will be established on the leases. The fill for the Cell A embankment lifts will be taken from borrow areas within Cell B. Likewise the fill for the Cell B embankments will be taken from within Cell C. Later fill requirements will be taken from external borrow area.

The geometry of each embankment lift will be as follows:

- Crest width – 4 m
- Lift height – 2 m
- Overall outer (downstream) slope – 1:3
- Upstream face slope – 1:1.5

The embankment lifts will not be lined. There will be no phreatic surface within the stored compacted residue, and therefore no hydrostatic loading on the peripheral embankments.

A decision will be made after the first few years of the operation whether to continue to raise Cell A to the final height or whether to begin construction of Cell B. Cell B will be followed by Cell C.

The advantage of developing Cell A to full height will be that further capital expenditure on initial embankment construction and HDPE lining (for Cells B and C) can be delayed. The advantage of having more than one cell in operation is that the rate of rise of the placed residue in each cell will be lower, and this may be beneficial in terms of the overall operation. A decision on the medium to longer term management strategy will be made early in the life of the project.

### 3.10 Equipment Requirements

The construction of the Stage 1 earth fill embankments will be carried out using conventional earthmoving equipment including:

Scrapers – to remove and stockpile topsoil from the embankment foundations and over the top of the borrow areas. The scrapers may also be used to excavate and place the fill into the embankments.

Dozers – used to rip areas within the borrow pits to allow the material to be moisture conditioned before being loaded out by the scrapers.

Water tankers – used for dust control on haul roads and to wet up the fill material in the borrow pits. The water tankers will also be used to maintain the optimum moisture content of the fill on the embankments during construction.

Graders – used to maintain haul roads and to level the fill in the embankments between lifts and to level the foundations of the storage cells prior to placing the HDPE liners.

Compactors – used to compact the placed fill to the in situ density required and to compact the foundations prior to placing the HDPE liners.

Excavators – used to trim the outer faces of the embankments.

The construction of the Stage 1 embankments will be a day shift operation. The working hours will be in accordance with the NSW guidelines.

The construction of the ongoing embankment lifts will require much the same equipment, however it is more likely that the fill will be taken from borrow pits by excavator, loaded into 6 wheel ATV trucks (typically 40 tonnes trucks would be used) and placed into the embankment lifts.

The construction of the ongoing embankment lifts will also be a day shift operation in accordance with the NSW guidelines.

### 3.11 Closure

At closure, it is likely that the upper surface of the residue in each cell will be slightly domed to enable the majority of rainfall runoff to be shed. The final cover will be based on the “store and release” system which will allow heavy rainfall to flow off the surface but hold, and then release by evaporation, lighter rainfall. Further details will be provided for approval well before the closure of the facility.

There will be minimal water passing through the cover to the compacted residue. The permeability of the residue will be very low, and since the material will be well below saturation levels, there will be no long term movement of water through the stack. The double liner, with an inter-liner monitoring system, will ensure that there is no release of seepage to the environment.

**Drawing 120-12-302** shows the cells when developed to the full height, i.e. after 20 years. The arrows indicate the general direction of drainage once the final cover has been placed. Further details of the system to take the incident rainfall runoff to discharge points at the bases of the embankments will be provided at the final design stage, but not constructed until closure. **Drawing 120-12-303** shows a typical section through the SRSF at closure.

## 4.0 LIQUID RESIDUE

### 4.1 Residue Quality

A large volume of water is used in plant during the extensive washing processes. At the end of the washing cycles the water contains impurities and cannot be re-used. The only practicable means of removing the water from the circuit is by evaporation. The water is referred to as Liquid Residue.

The water will have a salinity of 62 500 ppm when leaving the plant. The salinity in the liquid residue storage facility (LRSF) will gradually increase with the loss of volume by evaporation. As the salinity increases, salts will be deposited on the bases of the LRSF cells. This impact of the salt deposition will be discussed below.

As the LRSF cells are in effect allowing the deposited salts to semi crystallize, the term Salt Crystallisation Cells has been used on the Drawings. In practice, one or two of the cells will probably be used specifically to allow the salt to be crystallised to a solid form and be progressively recovered during the operating years of the project. These cells have not been identified at this stage.

## 4.2 Volumes

The total volume of liquid residue to be evaporated is likely to be around 2.4 Mm<sup>3</sup> each year. This equates to 200 000 m<sup>3</sup>/month.

Work is continuing on the development of filtration processes, including reverse osmosis, which can remove the impurities from the residue, and hence make the re-use of the water possible. This may further reduce the volume of water which is sent to the individual cells of the LRSF, and importantly the volume of make-up water required.

## 4.3 Evaporation Rates

The total number and area of individual cells, which make up the LRSF, required to lose all the water produced over a year of plant operation will be dependent on the net annual evaporation rates, i.e. evaporation minus rainfall. The evaporation rates and the rainfall will vary over the course of each year, and therefore the cells will be designed to allow a build up in the volume of water during the winter months.

The average gross pan evaporation in the Dubbo area is 2.06 m/a (Golders, October 2001). The average annual rainfall is estimated to be 600 mm. The net *pan evaporation* is therefore 1.46 m/a.

The peak evaporation occurs in the summer months, although the rainfall is fairly evenly distributed throughout the year. Peak net (pan) evaporation is in the region of 10 mm/day. The lowest net evaporation occurs in June/July, and is estimated to be 2.2 mm/day.

The Pan Factor (PF), i.e. the relationship between the measured pan evaporation and the actual loss of water by evaporation from a body of water, is difficult to estimate as there are many local factors involved. These include depth and temperature of the water, and the frequency and velocity of the wind. In earlier studies, a figure of 0.8 was assumed for the preliminary design. This figure has been used in this Report, however further investigations are ongoing.

The water to be lost by evaporation contains dissolved salts, and therefore the evaporation rates will be lower than for pure water. Work at other sites including the Ravensthorpe Nickel Operation (RNO), where over 200 ha of evaporation ponds are in operation, has shown that as the salinity increases, the rate of evaporation decreases. The WA Department of Agriculture has published a curve which links the pan evaporation rates with salinity as measured in mg/L. At 55 000 mg/L, the evaporation factor (ratio of pan evaporation to actual) is 0.9, i.e. 90%.

The overall relationship between pan evaporation (Met Bureau figures) and the actual losses from the cells of the LRSF is therefore assumed to be 0.72. **Table 4.1** gives the daily net (adjusted) evaporation rates which could be expected, i.e. pan evaporation x 0.72.

**Table 4.1 Adjusted Net Daily Evaporation Rates (mm)**

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Pan Evap.	9.8	8.5	6.7	4.5	2.8	2.2	2.2	2.8	3.8	5.7	8.0	10
Adjusted	7.05	6.12	4.82	3.24	2.01	1.60	1.60	2.0	2.73	4.10	5.76	7.2

The net annual evaporation loss from the ponds could be 1.05 m/a.

#### 4.4 Total Evaporation Area Required

The LRSF will provide both storage and evaporation area. As net evaporation rates vary throughout the year, the volume of water lost per month will also vary. This will require that the individual cells provide storage for the build up of water which occurs during low periods of net loss, and have sufficient capacity to contain the design storm event.

Based on an annual net evaporation loss of 1.05 m, an area of 230 ha will theoretically be required to lose the 2.4 Mm<sup>3</sup> of liquid residue produced each year. However because of the difficulties in accurately predicting the evaporation losses, the following dimensions for the LRSF have been allowed for in the initial construction program.

A total area of 425 ha.

An operating surface water (evaporative) area of 303 ha.

A total operating volume of 1.4 x 10<sup>7</sup> m<sup>3</sup>.

A water balance model is being completed to establish the optimum evaporation and storage capacity required. It is noted that this modelling will be based on evaporative rates that must be assumed based on available data and that actual evaporative rates may vary from the assumed. There will, however, be opportunity during the initial years of operation, as processing rates ramp up, to assess the actual evaporative rates achieved and review the water balance modelling. In the event additional area is required due to lower than anticipated evaporative rates, the appropriate approvals would be sought prior to constructing additional cells. Whilst these approvals are sought, the discharge of residue will be restricted to that which can be evaporated by the LRSF. Work is also continuing to find methods of reducing the overall project water usage.

### 5.0 DESIGN OF THE LRSF

#### 5.1 General

The individual cells of the LRSF will be constructed on land which will be owned by Australian Zirconia Limited and will form part of the mining lease for the Dubbo Zirconia Project. The land has been largely cleared of native vegetation for ongoing cropping and grazing, although occasional trees and areas of native grass remain over a proportion of the LRSF such that it meets the Scientific Committee of NSW definition for native woodland communities (including the endangered ecological community White Box Yellow Box Blakely's Red Gum Woodland).

Initial investigations of soil types, general terrain and other features likely to influence the suitability of land to the construction of the LRSF were completed by Sustainable Soils Management Pty Ltd (represented by the blue hatching on the **Drawing 120-12-100**). In total, approximately 600 ha of land was identified which satisfied the following six criteria.

1. The land is more than 200 m from the Wambangalang Creek and 50 m from drainage lines unless the area extends to the water shed.
2. The slope does not exceed 5%.
3. The land has been cleared, but may contain scattered trees.
4. There are no water discharge areas.

5. The minimum width of the land is 200 m.
6. The land is more than 50 m from known road reserves and does not include any known road reserves.

Initially seven (7) areas were identified for the construction of the individual cells of the LRSF, however, following improvement in process efficiency and water recycling this has been reduced to four (4) groups. The terrain varies from flat areas in closer proximity to Wambangalang Creek to steeper hill slopes to the east of the plant. Areas No's 2 and 3 are located on the flatter areas adjacent to, and north of the plant location. Areas 4 and 5 are located on the higher ground in the central part of the lease.

The liquid residue will be pumped to each group of cells balancing the volumes of water delivered with the performance of the cells.

Unless the life of the Proposal coincides with prolonged periods of above average rainfall, the total area of the water surface will likely be less than the 350 ha allowed.

## **5.2 Details of the LRSF Cells**

### **5.2.1 Topography**

The most efficient topography in terms of area created vs embankment volume required is a totally level site. Such areas are very limited in the local setting, even along the creek line adjacent to the plant site. The average cross fall for the lower areas (Areas 2 and 3) is around 1:35 (3% fall), while the cross-fall increases to around 4-5% for Areas No's 4 and 5.

As a result of the topography, the ponds will be formed by terracing the slopes using a series of contour embankments. In order to improve the efficiency of the individual cells, the bases of at least some of the cells will be made horizontal by re-graded ie using cut to fill to modify the foundations. The borrowing of the embankment fill from the higher ground at the rear of the cells will also help in this regard.

### **5.2.2 Foundation Conditions**

The sites of each of the LRSF Areas have been selected to provide competent foundation conditions and the opportunity to borrow material from within each pond to construct the embankments. A comprehensive site investigation of the soils landscapes and conditions of the project area has been carried out by Sustainable Soils Management Pty Ltd. The report is provided as Part 10 of the Specialist Consultant Studies Compendium accompanying the EIS for the Dubbo Zirconia Project. The investigation has enabled the identification of the areas most likely to be suitable for the development of the evaporation ponds (based on the criteria identified in Section 5.1). It is these areas which have been used in the preliminary design.

The areas are covered with a thin layer of topsoil, ranging from 100 mm on the Belowrie Soil landscape (parts of Area 4), 150 mm on the Wongarbone Soil Landscape (Area 5 and parts of Area 4) and up to 250 mm on the Ballimore Soil Landscape (Areas 2 and 3). Beneath the topsoil, the fine grained clayey soil (in situ weathering of the underlying basement rock) will be excavated and then compacted into a competent fill to form the embankments.

Topsoil to a depth of 150mm will be stripped from the area of the ponds and stockpiled beyond the final impact footprint. Subsoil to a depth of 500mm to 600mm will then be stripped, temporarily stockpiled before being used in the construction of inter-cell embankments. The remainder of the embankment will be constructed using deeper subsoil and subgrade from the cut and fill operations undertaken to level the base of each cell. The resultant cell floor will be cleared by grader and the whole foundation area moisture conditioned and compacted with several passes of a heavy duty compactor. A further inspection of the surface will be made before the HDPE liner is installed. Areas of topsoil will require extraction from beneath the outer and inter-cell embankment footprints as well and will either be placed within external stockpiles or re-spread over sections of the lower cell embankments.

The cut areas of each cell will be located against the up-slope edge with fill works at the embankment edge. A detailed site investigation will be carried out prior to final engineering design and construction to confirm geotechnical properties of the material to be used for fill and embankment construction.

### 5.3 Location of the LRSF Cells

The cells of the LRSF are divided into four (4) areas, Areas 2-5 (Areas 1, 6 and 7 originally proposed have been determined to be surplus to requirements following a reduction in the volume of liquid residue to be discharged).

**Table 5.1** provides details of the location of the Areas 2-5, the number of ponds in each area and the maximum surface area of the stored water. Note that the number of ponds is based on a preliminary design and it is likely that the sizes of the individual cells may vary from that shown on **Drawing 120-12-100**. This notwithstanding, the total area of disturbance for Areas 2 to 5 will not exceed that nominated in **Table 5.1** and critical areas of environmental constraint surrounding each area, e.g. biodiversity of conservation significance, cultural heritage features, local drainage features subject to flooding, etc., will be identified and exclude from any minor modification to LRSF design.

**Table 5.1 Evaporation Areas**

LRSF Area	Approximate location in relation to the plant	Potential No of Cells	Potential Evaporative Surface Area (ha)
2	North	4	26.5
3	Adjacent	7	69.5
4	North east	6	100.9
5	Due east	9	106.5
TOTAL		26	303.4

The actual areas occupied by each cell and the alignment of the embankments will be finalised following detailed site investigations and design.

The cells are shown in more detail on **Drawings 120-12-200** and **120-12-201**.

## 5.4 Embankments

The layout of the cells, shown on the drawings and used for the capital cost estimates, assumes that at each location the embankments follow the natural surface contour lines. There is an average 5 m cross fall over the bases of the ponds, meaning that the nominal height of the embankments could be 5 m. However an additional 1 m has been allowed for freeboard to provide for wave run-up (wind generated) and the containment of heavy rainfall, making the average embankment height 6 m as measured from the natural surface at the upstream toes.

Because of the topography, the cells tend to be long and relatively narrow. This arrangement has some advantages in terms of limiting the potential for wave run-up within each pond. Waves generated by wind can result in damage to pond liners and embankments. At the final design stage, the layout of each pond will be optimised in terms of shape and overall water area.

It is assumed that the fill for the embankments will be taken from within each cell area. The bases of each cell will be levelled by cut to fill, with the earthworks balanced to allow for the construction of the retaining embankments.

The embankments will have a nominal crest width of 4 m (the minimum required to allow a reasonable sized compactor to safely work on the upper levels) with 1:1.5 (vertical:horizontal) side slopes, except for the lowest (outer) embankment of each set of cells where the downstream slope will be 1:2.

A typical cross section through the embankments forming part of the Area 3 cells is given on **Drawing 120-12-204**.

Assuming that a total cell area of 425 ha is developed, the estimated total length of the LRSF embankments will be 30 km. Using an average embankment section of 70 m<sup>2</sup>, the overall volume of fill is estimated at 2.1 Mm<sup>3</sup>. This equates to approximately 6 000 m<sup>3</sup>/ha of pond area. This volume does not allow for the excavation of unsuitable foundation material and therefore a contingency of around 15% should be allowed.

The downstream slopes of these “outer” embankments will be grassed to protect against wind and rain erosion. Where there is the possibility of external water erosion, rock bunds will be provided, the rock being sourced from available mine waste rock.

Drainage will be provided around each group of ponds to ensure that the external catchment runoff is diverted away from the upper pond. A drainage plan is provide conceptually on the drawings of this report, however, a more formal plan will be prepared by others. A typical section showing the catchment diversion drainage is given on **Drawing 120-12-204**.

## 5.5 Construction Equipment

The construction of the earth fill embankments which form the LRSF cells within each defined area will be carried out using conventional earthmoving equipment including:

Scrapers – to remove and stockpile topsoil from the embankment foundations and over the top of the borrow areas. The scrapers may also be used to excavate and place the fill into the embankments.

Dozers – used to rip areas within the borrow pits to allow the material to be moisture conditioned before being loaded out by the scrapers.

Water tankers – used for dust control on haul roads and to wet up the fill material in the borrow pits. The water tankers will also be used to maintain the optimum moisture content of the fill on the embankments during construction.

Graders – used to maintain haul roads and to level the fill in the embankments between lifts and to level the foundations of the storage cells prior to placing the HDPE liner.

Compactors – used to compact the placed fill to the insitu density required and to compact the foundations prior to placing the HDPE liners.

Excavators – used to trim the outer faces of the embankments

It is assumed that the work to construct the cells will be carried out as a day shift operation. The ponds are likely to be progressively constructed, with sufficient capacity for the ramping up of the plant throughput. Construction of the ponds will be ongoing until monitoring shows that there is adequate area to permit the balancing of the incoming and outgoing (evaporation) liquid residue.

## **5.6 Lining**

The bases of the ponds and the faces of the embankments which form the ponds will be lined with a single 1.5 mm HDPE welded sheet.

The liners will be placed over a prepared foundation comprising compacted fine grained in situ material or, where the ground cannot be made sufficiently smooth, a layer of imported sand or a sheet of geotextile.

Both faces of the intermediate embankments will be covered with HDPE. Experience with the large evaporation ponds at the RNO in the southern part of WA suggests that making the liner continuous over the crests of the intermediate embankments will prevent saturation of the embankment crests, and a potential failure (slumping) of the embankment faces which if not controlled can place stress on the liners. A capping strip of HDPE will therefore be welded in place over the crests of the embankments once the HDPE liners have been secured on each face.

As the ponds will take some time to fill, the liners on both the embankment faces and the bases of the cells will be held in place by sand bags or disused car tyres, roped together to ensure that they cannot be displaced.

## **5.7 Freeboard**

The design storm for the calculation of freeboard will be the 1:10 000 year event. The total rainfall produced by this storm has been calculated at 460 mm.

It is planned to operate the ponds, under normal ambient conditions, with 1 m freeboard at the retaining embankments. Following a major storm event there should still be over 500 mm of freeboard. This freeboard will allow for wave run-up. It is likely that if rainfall of this magnitude was experienced at site, the total operation would be suspended for some period, thus allowing the level of the liquid residue in the ponds to reduce. There are no contingency plans to have an emergency release of water.

## 6.0 OPERATION OF THE LRSF

### 6.1 Distribution of Liquid Residue

The cells contained within Areas 2-5 which comprise the LRSF will be tiered. In order to minimise the possibility of the ponds overtopping, the liquid residue will be discharged into the ponds through individual valved outlets on the main delivery pipelines. The cells vary in size and therefore the rate at which the liquid residue is lost will also vary. There will be a discharge point for each cell. This will enable each cell to be filled, and kept topped up, under a pre-determined program, thus ensuring that the evaporation area is maximised, and that there will always be adequate freeboard for the containment of rainfall and the design storm event.

The pipelines will be sized to ensure that all pipes operate under a low pressure thus reducing the potential for failure. The pipes will be constructed from welded HDPE. Where the pipes traverse open ground between the plant and the LRSF, the pipes will be in banded trenches. At all road crossings, the pipes will be placed in concrete culvert pipes to allow the residue pipes to be serviced. Flow meters with remote readout will be installed on all the major pipelines and at each discharge point. A pipe break or major leak will be automatically detected by the plant control software which will continually compare flow reading to different parts of the LRSF. Regular (every shift) visual monitoring of the pipes and cells will be used to detect minor leakage. Isolation valves on all pipelines will be used to turn off the flow to enable repairs to be carried out.

**Drawing 120-12-200** shows a detail of the access roads and banded pipe trenches which will be provided to each cell area.

With the exception of the lowest elevation cell within each area, an emergency spillway will be constructed in the embankment of each cell. A spillway is necessary to protect the embankment and to direct any emergency release of water. However the emergency spillways will allow a cascading effect between the cells, i.e. the overflow from the top cell may result in the next (lowest) cell also overflowing via the spillway in that cell. In order to prevent a release of water from each group of cells, the lowest cell will be operated with additional freeboard.

### 6.2 Monitoring

The pumping of the liquid residue to the LRSF ponds will be closely monitored throughout the life of the project. Whilst the calculated area required to allow an on-site water balance has utilised all available data, experience with other operations suggests that the number of ponds in active service may have to be changed from time to time depending on the variation in ambient conditions and in the quality of water being discharged to the ponds.

Once each cell has been completed, i.e. embankments constructed and the liners installed, an accurate survey will be undertaken and the depth/volume and depth area curves for each cell determined.

An accurately marked level staff will be installed in each pond to allow the water level to be read without the need to a formal survey. A protective floating ring around the staff will nullify the impact of wave height on the reading. Alternatively an electronic water level system will be trialled, however, the impact of the salt build up may impact on the accuracy of the readings.

Several standard evaporation pans (Australian Standard Class A pans) will be located around the project site. By monitoring the volume of water discharged to each cell and the change in the water level (and hence surface area) a data base which measures the performance of the cells can be progressively built. This data base will then allow the overall evaporation area to be optimised, and a timely warning given of the need to add additional area. Regular comparisons between the Class A pan data and the actual data will be valuable in this regard.

In addition to the volumetric monitoring of the ponds, multiple bores will be installed around all of the evaporation pond areas to monitor the groundwater movement and quality. The LRSF drawings show nominal locations for the monitor bores. The exact location for the bores will be determined by reference to the geology and hydrogeology at each location.

### **6.3 Closure**

Once the LRSF is no longer required, each cell will be decommissioned. This process will involve the following:

- Allow all remaining liquid residue to evaporate and the residual salt to crystallise to the greatest extent possible.
- Remove all the crystallised salt by wheeled loader and then (possibly) water jetting with the remaining liquid pumped to one of the other (still active) cells.
- Cut up and remove the HDPE liner, disposing of the liner off site via a recycling contractor.
- Push over the embankment restoring the site back to the original contours.
- Cover the replaced embankment fill and the previous embankment foundation area with topsoil brought in from stockpiles.
- Rip the whole area of the cell several times to break up and aerate the upper soil profile, and if required build up the soil nutrients by adding fertiliser etc.
- Plant the area with selected local (native) species or alternatively return the site to cropping/grazing farmland.

## **7.0 SALT STORAGE**

### **7.1 Estimated Quantity**

The loss of process water by evaporation will result in the deposition of a layer of salt over the bases of each cell. At the end of the operational life of the storage (or during the project life if separate crystallisation cells are used), the salt will be collected and placed into a permanent on site storage or alternatively transported from site to an external secure storage facility. Once the salt has been removed, the HDPE liners will be removed and sent off site for recycling of the HDPE material.

It is estimated that there will be approximately 7 Mt of salt deposited over the 20 year life of the operation.

This section of the Report describes the development of an onsite permanent storage area for the salt.

## 7.2 Physical and Chemical Properties

It is expected that the dehydrated salt remaining in the LRSF will be a solid with a high moisture content that will be amenable to physically handled with earth moving machinery.

The chemical composition of the salt remaining in the evaporation ponds is expected to be as shown in **Table 7.1** below.

**Table 7.1 Chemical composition of the Residual Salt**

Mineral	Residual salt in LRSF wt %
Al	0.10
Ca	0.05
Ce	< 0.01
Cl	17.8
Fe	< 0.01
Hf	< 0.01
K	0.04
La	< 0.01
Mg	0.47
Mn	0.01
Na	22.4
Nb	< 0.01
Nd	< 0.01
Ni	< 0.01
P	< 0.01
S	11.8
Si	0.01
Ta	< 0.01
U	0.02
Y	< 0.01
Yb	< 0.01
Zn	< 0.01
Zr	0.03

Note that the chemical analysis does not add up to 100%. This is because oxide forms of the above elements occur (SO<sub>4</sub> for example) as well as some hydroxide forms and there is some water retained in the salt.

### 7.3 Location

The salt storage area will be developed in the same general area as the SRSF cells. The salt storage will abut the southern cell (Cell B) of the SRSF.

The site for the salt storage was selected for the following reasons:

- Close to the mine waste rock stockpile and a potential source of long term cover
- On high ground without an significant catchment area around the site
- Close to the solid waste storage and the availability of equipment
- Foundation conditions competent
- Groundwater level well below surface (12m to 20m) (Golders, 2001; EES, 2013)

### 7.4 Removal of the Salt

Once the water in the evaporation ponds has been removed by a combination of evaporation and pumping, the salt will be allowed to crystallise. The pumping of retained residue between the completed cells will allow the evaporative and crystallisation process to be progressively completed in individual cells rather than having to wait for the process to complete for the entire LRSF. A rubber tracked FEL will be used to scrape up the salt and load the material into trucks for transport to the storage area. Any small amount of salt remaining on the liner will be removed by water jet and the solution pumped away to a lined pond (for secondary crystallisation and eventual recovery) before the liner is removed.

### 7.5 Description of the Storage Cells

The storage cells will be formed by the construction of earth and rock fill embankments. The storage cells will be fully lined with a double HDPE liner with a leak detection layer in between the liners.

While it is most unlikely that the well designed and constructed liner system will fail, the leak detection system will allow any water which passes through the upper liner to drain to monitor pits downstream of the external embankments. The pits could also be used to collect and pump water to the plant for treatment. If leakage is detected following the closure of the project, arrangement would be made to install permanent solar operated pumps to deliver the seepage to one of the previously used LRSF cells for evaporation. Bores will be installed around the site to monitor groundwater level and quality.

**Drawing 120-12-400** shows a plan of the first two cells. **Drawing 120-12-401** shows a typical embankment section.

The embankments will be constructed to final height before the liners are installed. Up to six cells are shown on the drawings, however not all may be required. The embankments will be constructed from earth fill (Zone A) borrowed from within each basin together with non sulphidic mine waste rock (Zone B). The earth fill will be placed and compacted into the embankments in 300 mm lifts. The rock will be placed in 1 m lifts.

The geometry of the embankments will be as follows:

Crest width – 6 m

Downstream face slope – 1:2

Upstream (lined) face slope – 1:1.5

## 7.6 Placement of the Salt into the Storage Cells

The salt will be excavated from the bases of the evaporation cells as a semi solid low moisture content material. The material will be loaded into trucks and dumped into the salt storage cells. Access to the top of the retaining embankments will be by temporary earth fill ramps. Tipping locations round the cells will be provided with chutes comprising layers of geotextile to protect the liners.

It is expected that the salt will be in the form of a semi liquid, crystalline slurry which will flow to some extent, and therefore self level within the storage cells. There should be no requirement to use mechanical equipment to move the salt around once dumped.

## 7.7 Management of Water

There is likely to be some highly saline water released from the salt. Water will also be collected on the surface of the deposited salt from incident rainfall. While it is expected that each cell of the salt storage will be filled quickly (thereby limiting the volume of incident rainfall collected by the active cell), a pumping system will be installed to remove excess water. The exact form of the pumping system will be determined once the condition of the salt waste has been confirmed. Experience gained in the salt industry will be used to assist in this regard.

The water which is removed is likely to be highly saline. The water will be returned to a lined evaporation cell to remove the bulk of the water before the salt is returned to the cells for final storage.

## 7.8 Closure

Once the upper surface of the salt in the storage cells has dried to the stage where the surface can be accessed by mechanical equipment, the surface will be covered with a layer of clay (or alternatively a synthetic material such as bentonite mat) to prevent ingress of rain water. The clay will be protected from desiccation by a layer of mine waste rock. Water falling on upper surface of the cells will shed via a series of engineered drains to discharge at the toe of the embankments. Full details will be provided well before the construction of the cells begins.

**Drawing 120-12-402** shows the salt cells at closure.

# **Appendix A**

## **Geotechnical Testing of Solid Residue**

A full colour version of this appendix is provided on the Project CD

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**MEMORANDUM**

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<b>TO:</b>	Alex Ryan, TZMI	<b>DATE:</b>	08 October 2012
<b>FROM:</b>	Mervyn Ovinis, ANSTO Minerals	<b>No. of Pages:</b>	1 inclusive
<b>SUBJECT:</b>	Preparation of Dubbo Composite Solid Waste		

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Dear Alex,

As part of the Dubbo Zirconia Project, ANSTO Minerals, based in Lucas Heights, NSW, prepared a bulk composite solid waste sample which involved the following steps:

- 1) Identifying each solid waste stream according to the process flowsheet;
- 2) Determining the wet mass required for each waste stream according to the mass balance and individual wet solid moisture contents;
- 3) Weighing out the wet solids mass of each stream and combining them using a mixer (twin shaft rotary blade solid mixer);
- 4) Adding lime to neutralise any acidity within the solid paste;
- 5) Recycling the generated solid paste several times to ensure homogeneity.

Approximately 10 x 5 kg<sub>dry</sub> samples were prepared, double bagged and heat sealed for storage and transport. Further details of the preparation process are found in a Technical Note: AM/TN/2012\_23\_7.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'Mervyn Ovinis', is written over a light blue horizontal line.

Mervyn Ovinis  
ANSTO Minerals

**ANSTO ZIRCONIUM ORE (TRACHYTE)**

Chemwatch Material Safety Data Sheet

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NC317TCP

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**Section 1 - CHEMICAL PRODUCT AND COMPANY IDENTIFICATION**

**PRODUCT NAME**

ANSTO ZIRCONIUM ORE (TRACHYTE)

**SYNONYMS**

**PRODUCT USE**

Process feed material.

**SUPPLIER**

Company: Australian Nuclear Science And Technology

Organisation

Address:

New Illawarra Road

Lucas Heights

NSW, 2234

AUS

Telephone: +61 2 9717 3111

Fax: +61 2 9543 5097

**Section 2 - HAZARDS IDENTIFICATION**

**STATEMENT OF HAZARDOUS NATURE**

NON-HAZARDOUS SUBSTANCE. NON-DANGEROUS GOODS. According to the Criteria of NOHSC, and the ADG Code.

**POISONS SCHEDULE**

None

**RISK**

None under normal operating conditions.

**SAFETY**

Avoid contact with skin.

**Section 3 - COMPOSITION / INFORMATION ON INGREDIENTS**

NAME	CAS RN	%
feldspars	68476-25-5	30-60
albite		30-60
aegirine		10-30
silica crystalline - quartz	14808-60-7	<5 <sup>^</sup>
zirconium dioxide	1314-23-4	<5 <sup>^</sup>
yttrium(III) oxide	1314-36-9	<1 <sup>^</sup>
cerium(III) oxide	1345-13-7	<1 <sup>^</sup>
lanthanum oxide	1312-81-8	<1 <sup>^</sup>
niobium(V) oxide	1313-96-8	<1 <sup>^</sup>
uranium mixed oxides (U3O8)	1344-59-8	<0.1 <sup>^</sup>
thorium	7440-29-1	<0.1 <sup>^</sup>

continued...



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### Section 4 - FIRST AID MEASURES

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#### SWALLOWED

- Considered an unlikely route of entry in commercial/industrial environments.
- Immediately give a glass of water.
- First aid is not generally required. If in doubt, contact a Poisons Information Centre or a doctor.

#### EYE

- If this product comes in contact with the eyes:
  - Wash out immediately with fresh running water.
  - Ensure complete irrigation of the eye by keeping eyelids apart and away from eye and moving the eyelids by occasionally lifting the upper and lower lids.
  - If pain persists or recurs seek medical attention.
  - Removal of contact lenses after an eye injury should only be undertaken by skilled personnel.

#### SKIN

- If skin or hair contact occurs:
  - Flush skin and hair with running water (and soap if available).
  - Seek medical attention in event of irritation.

#### INHALED

- If dust is inhaled, remove from contaminated area.
- Encourage patient to blow nose to ensure clear passage of breathing.
- If irritation or discomfort persists seek medical attention.

#### NOTES TO PHYSICIAN

Treat symptomatically.

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### Section 5 - FIRE FIGHTING MEASURES

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#### EXTINGUISHING MEDIA

- There is no restriction on the type of extinguisher which may be used.

#### FIRE FIGHTING

- Alert Fire Brigade and tell them location and nature of hazard.
- Wear breathing apparatus plus protective gloves for fire only.
- Prevent, by any means available, spillage from entering drains or water courses.
- Use fire fighting procedures suitable for surrounding area.
- DO NOT approach containers suspected to be hot.
- Cool fire exposed containers with water spray from a protected location.
- If safe to do so, remove containers from path of fire.
- Equipment should be thoroughly decontaminated after use.

#### FIRE/EXPLOSION HAZARD

- Non combustible.
- Not considered a significant fire risk, however containers may burn.

#### FIRE INCOMPATIBILITY

None known.

continued...

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 Section 5 - FIRE FIGHTING MEASURES

HAZCHEM: None

**Section 6 - ACCIDENTAL RELEASE MEASURES**

**EMERGENCY PROCEDURES**

**MINOR SPILLS**

- Clean up all spills immediately.
- Secure load if safe to do so.
- Bundle/collect recoverable product.
- Collect remaining material in containers with covers for disposal.

**MAJOR SPILLS**

- Clean up all spills immediately.
- Secure load if safe to do so.
- Bundle/collect recoverable product.
- Collect remaining material in containers with covers for disposal.

Personal Protective Equipment advice is contained in Section 8 of the MSDS.

**Section 7 - HANDLING AND STORAGE**

**PROCEDURE FOR HANDLING**

- Limit all unnecessary personal contact.
- Wear protective clothing when risk of exposure occurs.
- Use in a well-ventilated area.
- When handling DO NOT eat, drink or smoke.
- Always wash hands with soap and water after handling.
- Avoid physical damage to containers.
- Use good occupational work practice.
- Observe manufacturer's storing and handling recommendations.

**SUITABLE CONTAINER**

No restriction on the type of containers. Packing as recommended by manufacturer. Check all material is clearly labelled.

**STORAGE INCOMPATIBILITY**

None known.

**STORAGE REQUIREMENTS**

Store away from incompatible materials.

**Section 8 - EXPOSURE CONTROLS / PERSONAL PROTECTION**

**EXPOSURE CONTROLS**

Source	Material	TWA ppm	TWA mg/m <sup>3</sup>	STEL ppm	STEL mg/m <sup>3</sup>	Peak ppm	Peak mg/m <sup>3</sup>	TWA F/CC
Australia Exposure	feldspars		10					

continued...



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### Section 8 - EXPOSURE CONTROLS / PERSONAL PROTECTION

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Standards (Inspirable dust  
(Not specified))

#### MATERIAL DATA

Not available. Refer to individual constituents.

#### PERSONAL PROTECTION

##### EYE

- Safety glasses.
- Safety glasses with side shields.
- Chemical goggles.
- Contact lenses may pose a special hazard; soft contact lenses may absorb and concentrate irritants. A written policy document, describing the wearing of lens or restrictions on use, should be created for each workplace or task. This should include a review of lens absorption and adsorption for the class of chemicals in use and an account of injury experience. Medical and first-aid personnel should be trained in their removal and suitable equipment should be readily available. In the event of chemical exposure, begin eye irrigation immediately and remove contact lens as soon as practicable. Lens should be removed at the first signs of eye redness or irritation - lens should be removed in a clean environment only after workers have washed hands thoroughly. [CDC NIOSH Current Intelligence Bulletin 59].

##### HANDS/FEET

Use a dust mask when handling.  
Wear general protective gloves, eg. light weight rubber gloves.

##### OTHER

No special equipment needed when handling small quantities.

##### OTHERWISE:

- Overalls.
- Barrier cream.
- Eyewash unit.

The local concentration of material, quantity and conditions of use determine the type of personal protective equipment required.

For further information consult site specific  
CHEMWATCH data (if available), or your  
Occupational Health and Safety Advisor.

#### ENGINEERING CONTROLS

Avoid breathing generated dust when cutting, finishing. If risk of dust inhalation exists wear dust mask/ respirator.  
General exhaust is adequate under normal operating conditions. If risk of overexposure exists, wear SAA approved respirator. Correct fit is essential to obtain adequate protection. Provide adequate ventilation in warehouse or closed storage areas. Air contaminants generated in the workplace possess varying "escape" velocities which, in turn, determine the "capture velocities" of fresh circulating air required to effectively remove the contaminant.

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### Section 8 - EXPOSURE CONTROLS / PERSONAL PROTECTION

Type of Contaminant: solvent, vapours, degreasing etc., evaporating from tank (in still air)	Air Speed: 0.25- 0.5 m/s (50- 100 f/min)
aerosols, fumes from pouring operations, intermittent container filling, low speed conveyer transfers, welding, spray drift, plating acid fumes, pickling (released at low velocity into zone of active generation)	0.5- 1 m/s (100- 200 f/min.)
direct spray, spray painting in shallow booths, drum filling, conveyer loading, crusher dusts, gas discharge (active generation into zone of rapid air motion)	1- 2.5 m/s (200- 500 f/min)
grinding, abrasive blasting, tumbling, high speed wheel generated dusts (released at high initial velocity into zone of very high rapid air motion).	2.5- 10 m/s (500- 2000 f/min.)

Within each range the appropriate value depends on:

Lower end of the range	Upper end of the range
1: Room air currents minimal or favourable to capture	1: Disturbing room air currents
2: Contaminants of low toxicity or of nuisance value only	2: Contaminants of high toxicity
3: Intermittent, low production.	3: High production, heavy use
4: Large hood or large air mass in motion	4: Small hood - local control only

Simple theory shows that air velocity falls rapidly with distance away from the opening of a simple extraction pipe. Velocity generally decreases with the square of distance from the extraction point (in simple cases). Therefore the air speed at the extraction point should be adjusted, accordingly, after reference to distance from the contaminating source. The air velocity at the extraction fan, for example, should be a minimum of 1-2 m/s (200-400 f/min.) for extraction of solvents generated in a tank 2 meters distant from the extraction point. Other mechanical considerations, producing performance deficits within the extraction apparatus, make it essential that theoretical air velocities are multiplied by factors of 10 or more when extraction systems are installed or used.

### Section 9 - PHYSICAL AND CHEMICAL PROPERTIES

#### APPEARANCE

Sage green/cream/brown coloured rock; insoluble in water.

#### PHYSICAL PROPERTIES

Does not mix with water.  
Sinks in water.

Molecular Weight: Not Applicable  
Melting Range (°C): Not Applicable  
Solubility in water (g/L): Immiscible  
pH (1% solution): Not Applicable  
Volatile Component (%vol): Not Applicable  
Relative Vapour Density (air=1): Not Applicable  
Lower Explosive Limit (%): Not Applicable

Boiling Range (°C): Not Applicable  
Specific Gravity (water=1): 2.7  
pH (as supplied): Not Applicable  
Vapour Pressure (kPa): Not Applicable  
Evaporation Rate: Not Applicable  
Flash Point (°C): Not Applicable  
Upper Explosive Limit (%): Not Applicable

continued...

## ANSTO ZIRCONIUM ORE (TRACHYTE)

Chemwatch Material Safety Data Sheet  
Issue Date: 9-Jan-2007  
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### Section 9 - PHYSICAL AND CHEMICAL PROPERTIES

Autoignition Temp (°C): Not Applicable  
State: Manufactured

Decomposition Temp (°C): Not Available  
Viscosity: Not Applicable

### Section 10 - CHEMICAL STABILITY AND REACTIVITY INFORMATION

#### CONDITIONS CONTRIBUTING TO INSTABILITY

Product is considered stable and hazardous polymerisation will not occur.

### Section 11 - TOXICOLOGICAL INFORMATION

#### POTENTIAL HEALTH EFFECTS

##### ACUTE HEALTH EFFECTS

###### SWALLOWED

Considered an unlikely route of entry in commercial/industrial environments. The material has NOT been classified by EC Directives or other classification systems as "harmful by ingestion". This is because of the lack of corroborating animal or human evidence. The material may still be damaging to the health of the individual, following ingestion, especially where pre-existing organ (eg. liver, kidney) damage is evident. Present definitions of harmful or toxic substances are generally based on doses producing mortality rather than those producing morbidity (disease, ill-health). Gastrointestinal tract discomfort may produce nausea and vomiting. In an occupational setting however, ingestion of insignificant quantities is not thought to be cause for concern.

###### EYE

The dust may produce eye discomfort causing smarting, pain and redness.

###### SKIN

The material is not thought to produce adverse health effects or skin irritation following contact (as classified by EC Directives using animal models). Nevertheless, good hygiene practice requires that exposure be kept to a minimum and that suitable gloves be used in an occupational setting.

###### INHALED

The material is not thought to produce adverse health effects or irritation of the respiratory tract (as classified by EC Directives using animal models). Nevertheless, good hygiene practice requires that exposure be kept to a minimum and that suitable control measures be used in an occupational setting. Persons with impaired respiratory function, airway diseases and conditions such as emphysema or chronic bronchitis, may incur further disability if excessive concentrations of particulate are inhaled.

###### CHRONIC HEALTH EFFECTS

As with any chemical product, contact with unprotected bare skin; inhalation of vapour, mist or dust in work place atmosphere; or ingestion in any form, should be avoided by observing good occupational work practice.

#### TOXICITY AND IRRITATION

Not available. Refer to individual constituents.

FELDSPARS:

continued...

**ANSTO ZIRCONIUM ORE (TRACHYTE)**

Chemwatch Material Safety Data Sheet

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**Section 11 - TOXICOLOGICAL INFORMATION**

No data of toxicological significance identified in literature search.

**Section 12 - ECOLOGICAL INFORMATION**

DO NOT discharge into sewer or waterways.

**Section 13 - DISPOSAL CONSIDERATIONS**

- Recycle wherever possible or consult manufacturer for recycling options.
- Consult State Land Waste Management Authority for disposal.
- Bury residue in an authorised landfill.
- Recycle containers if possible, or dispose of in an authorised landfill.

**Section 14 - TRANSPORTATION INFORMATION**

HAZCHEM: None

NOT REGULATED FOR TRANSPORT OF DANGEROUS GOODS:UN, IATA, IMDG

**Section 15 - REGULATORY INFORMATION**

POISONS SCHEDULE: None

**REGULATIONS**

feldspars (CAS: 68476-25-5) is found on the following regulatory lists;  
 Australia Exposure Standards  
 Australia Inventory of Chemical Substances (AICS)  
 OECD Representative List of High Production Volume (HPV) Chemicals

**Section 16 - OTHER INFORMATION**

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Issue Date: 9-Jan-2007

Print Date: 9-Jan-2007



Dubbo wastes

Solid waste components

The mass balance of the current campaign was used to determine the dry solid proportions required of all the Dubbo solid waste streams to be mixed to yield a representative solid waste stream. Moisture content of actual samples were then used to calculate the mass of wet solid wastes required.

The mass of the various streams are denoted in Table 1

**Table 1**  
Mass Balance of Solid Waste Streams from Proposed Dubbo Fluoride Process

Waste stream	Solids (t/h)	wt% solid	% Total	Dry Mass Needed (kg)	Wet Mass Needed
<i>Fluoride Process</i>					kg
Fe Cake	10	43.1	30.57	30.57	70.93
Al Cake	0.68	32.8	2.08	2.08	6.34
HREE SL Residue	0.013	47.1	0.04	0.04	0.0844
LREE Leach Residue	22	74.2	67.26	67.26	90.64
LREE SL Residue	0.017	41.33	0.05	0.05	0.126
Total	32.7			100	168.12

The collected solids were then divided into individual portions for the ease of use and management. The sizes of each of the portions are as listed in Table 2.

**Table 2**  
Portions of Wet Solid Divided in Preparation

Waste stream	Bags	Mass of Ea Bag	Total
<i>Fluoride Process</i>			kg
Fe Cake -1	10	5.000	50.00
Fe Cake -2	10	2.093	20.93
Al Cake	10	0.634	6.34
HREE SL Residue	10	0.0084	0.084
LREE Leach Residue	20	4.532	90.64
LREE SL Residue	10	0.0126	0.126
Total			168.12

The combination of each of the bag, and 2 of the LREE Leach residue bags constitutes 10% of the total 100 Kg dry solid to be produced.

The solid mixer utilized is a Pug-Mill that was originally designed to mix and extrude clay. The machine utilises a tall vertical chute to feed the twin bladed shaft that will mix and transport the solid along its body. The twin shaft ends about 50 mm prior to the end of the bodies' length. At the end of the main transport body exists an extrusion head. The extrusion head narrows the exit portal of the mixer, creating an increase in pressure and decrease in velocity of the solid transport.



**Figure 1**  
Pugmill (without Extrusion head and Chute Extension) and Twin Rotary Blades

LREE Leach Residue filter cake was used as an initial test of the mixer. The residue was added at a slow rate whilst the mixer was operating at a high rotation rate (40Hz). Visual observations noted that the solids were quickly transported to where the twin shafts ended in the bodies' length. With further addition, the blades continued to transport the solids to the end of its length whilst being coated with the sticky part of the wet residue.

The chute was then filled with further solids, to tests the machines ability to push the solid past the extrusion plate. It was found that no solid was exiting the extrusion head however even when the entire length of the working volume was filled. It was observed that the high rotation rate of the bladed shafts had worked the solids around it into a viscous slurry. The viscous slurry was flowing back and forth about the blades as they quickly turned.

Upon Inspection of the extrusion plates, it was found that the solids had been packed inside it. Upon removal of the built up packed solids, the viscous slurry was observed to have found its exit path out of the extrusion head where it flowed out like a slurry waterfall. The rate of rotation was quickly taken down to its slowest rate (2Hz) where it continued to move the viscous slurry through its length. It was observed that the slurry of solid looked a lot moister then the original solid fed to the mixer. It was proposed that this was due to the rate of mixing had caused the solid to dewater within itself.



**Figure 2**

Dewatering of solids causes a solid flow that looks quite viscous and wet. Extrusion head is attached.

A different tact was used for the mixing of the actual samples for the representative mixture. The chute was completely filled with the solids required prior to starting the rotary shafts. The portions were added in the following order:

- 1 bag LREE Leach residue
- 1 5 kg bag Fe Cake
- 1 bag of Al cake
- 1 portion of LREE SLR
- 1 portion of HREE SLR
- 1 2.093 kg bag of Fe Cake
- 1 bag of LREE Leach residue

It was found that two of these portions (20% total) were required to completely fill up the chute. The solids however were only dropped in and were not tightly packed.

The Rotary blades were then commenced at a slow rate (2Hz). It was found that the solids in the chute were consumed at a slow comfortable pace. The solids reaching the extrusion plate looked to have been a nicely crumbled version of the filter cakes added.



**Figure 3**

Filter cake after first pass through, with Rotary Blades and Extrusion Head.

As the chute continued to empty, a 3<sup>rd</sup> portion of the solids were added to the chute so that a continual feed was in place to feed the rotary blades. The machine continued to work, with more solids filling up the volume at the extrusion head. When it was looking promising, the forward velocity of the solids appeared to have slowed even though the chute had plenty of solids to feed. It was then noticed that the twin blades had physically stopped. Increasing the rotation rate (to 4.5 Hz) was found to have started the rotary again but only to stop again. The rotation rate was then increased again (to 7Hz) where it was found to continue to rotate and move the solid along further. The solid transport however stopped again, but the rotary blades did not. This indicated that with the extrusion plate, the solids still blocked the exit path at the slower rotation rates.

As a result, the solids compacted at the exit end was removed, and a flow of evenly mixed solids was observed to be able to flow out of the extrusion plate.

It was observed that the chute was emptied and the entry at the body was not at capacity either. It was decided that a 4<sup>th</sup> and 5<sup>th</sup> portion of the solids would be added to the mixer to ensure a continual feed in the chute to the rotary blades, to keep the process continual.



**Figure 4**  
Mixture Exiting Extrusion Head Prior to blocking up with 5<sup>th</sup> batch.

The 4<sup>th</sup> and 5<sup>th</sup> batch was added slowly between each slug of returned mixed solid. This was done so that the alternating feed consistency would hopefully not cause blockage issues with the extrusion head. Unfortunately, as the 5<sup>th</sup> batch was about to be added, it was found that the solid transport had once again stopped at the extrusion head.

It was decided that it was best to remove the extrusion head to allow for unrestricted transport. The 5<sup>th</sup> batch was added without further issues. It was observed though that the transport out of the rig was as fast as the solid could be fed back in. The solid was mixed but still contained granular hard pieces that could be felt through the soft pasty mixture.

As the mixture was better mixed at this stage, the extrusion head was replaced to try to promote the mixing of the residual granular solid bits. The mixture was able to, at this point, flow through the extrusion head without issue and the solid was recirculated a few times for ensured mixing. It is also noted that at this working volume, the mixer was at about 95% working capacity with only little head space left in the chute.

A solid sample was taken and mixed with water at a 1:3 ratio (Mass Wet Solid: Mass Water) and the resulting slurry was analysed for pH. The pH was found to be 6.02. This suggests that the pH of the moisture in the solids is roughly pH 5.4. Through addition of solid lime, it was found that less than 0.08g of solid hydrated lime, per 40g of solids, was required to raise the pH of the solid above pH 7.

With this ratio in mind, 130g of Hydrated lime was added to the bulk batch, via a spoon full with each recirculated solid slug (roughly 2kg each) to ensure good mixture. The pH of the now neutralised solid will require a new pH to ensure its neutralisation.

The mixture was then recirculated a few times before being separated into 10 portions. The 10 portions were collected sequentially, with each bag collecting one slug of solid at a time to equally separate the solid between the portions. 60 ml jars were also used to collect a smaller portion of each and every slug removed from the mixer to use as the representative sample.

These samples will need to be mixed and then appropriately prepared for the analysis required.



## TEST CERTIFICATE

au.ind.perth.admin@sgs.com  
ABN: 44 001 994 276  
ph. 1300 791 744  
fx (08) 9378 0199

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SGS Australia Pty Ltd  
PO Box 486 Bassendean WA 6934  
5 Yelland Way  
Bassendean WA 6054

Client:	D E Cooper & Associates Pty Ltd	Client Job No:	
Order No:		Project:	
Tested Date:	30/10/2012	Location:	
SGS Job Number:	12-01-2018	Sample No:	12-MT-9138
Lab:	Bassendean	Sample ID:	Solid waste 08-08-12

### ATTERBERG LIMITS (PLASTICITY INDEX)

AS1289.3.1.2(Liquid Limit), 3.2.1(Plastic Limit), 3.3.1(Plasticity Index), 3.4.1(Linear Shrinkage)

<b>AS 1289.3.1.2</b>	
Liquid Limit (%)	45
<b>AS 1289.3.2.1</b>	
Plastic Limit (%)	37
<b>AS 1289.3.3.1</b>	
Plastic Index (%)	8
<b>AS 1289.3.4.1</b>	
Linear Shrinkage (%)	3.0
Nature of shrinkage	Flat
Length of Mould (mm):	125
History of Sample	Oven Dried <50°C
Method of Preparation	Dry Sieved

Note: Sample supplied by client.

Approved Signatory:  (Jason Jones)

Date: 2/11/2012



Accredited for compliance with ISO/IEC 17025

Accreditation No.: 2418 Form No. PF-(AU)-[IND(MTE)]-TE-S312.LCER/B/27.05.09  
Client Address: 85A Evans Street Shenton Park WA 6008

Site No.: 2411  
Cert No.: 12-MT-9138-S312  
Page: 1 of 1



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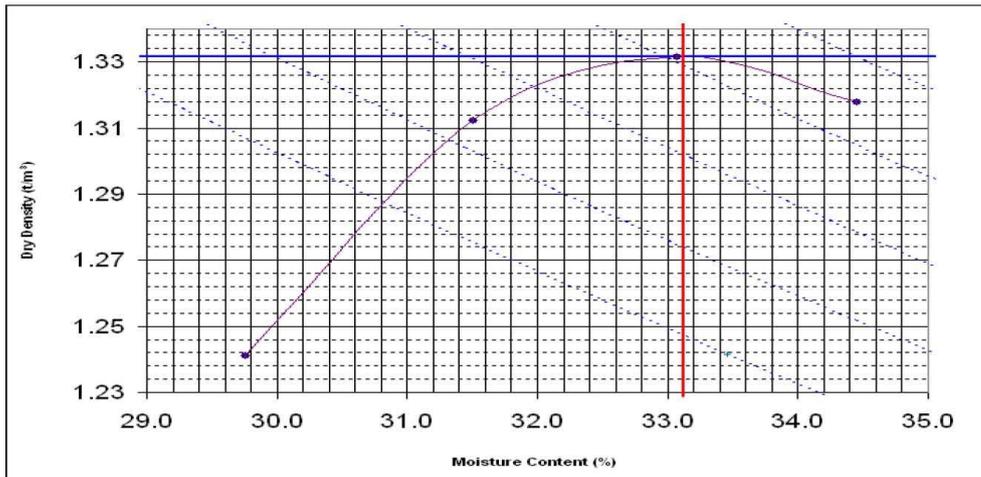
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Client:	D E Cooper & Associates Pty Ltd	Client Job No:	
Order No:		Project:	Dubbo Zirconia Project
Tested Date:	23/10/2012	Location:	
SGS Job Number:	12-01-2018	Sample No:	12-MT-9138
Lab:	Bassendean	Sample ID:	Solid waste 08-08-12

**DRY DENSITY/MOISTURE CONTENT RELATIONSHIP OF A SOIL**

AS 1289.5.1.1 (Standard Compactive Effort)



Standard Effort

Maximum Dry Density (t/m <sup>3</sup> ):	1.33
Optimum Moisture Content (%)	33.0
% Retained 37.5 mm	0
% Retained 19.0mm	0
Air Voids:	Voids %: 0 - 2 - 4 - 6 - 8 at SPD: 2.46

Note: Sample supplied by client.

Approved Signatory:  (Jason Jones)

Date: 25/10/2012



Accredited for compliance with ISO/IEC 17025

Accreditation No.: 2418 Form No. PF-(AU)-[IND(MTE)]-TE-S400.LCER/A/01.01.2009  
 Client Address: 85A Evans Street Shenton Parl WA 6008

Site No.: 2411  
 Cert No.: 12-MT-9138-S400  
 Page: 1 of 1





## TRIAxIAL SHEAR TEST REPORT CERTIFICATE

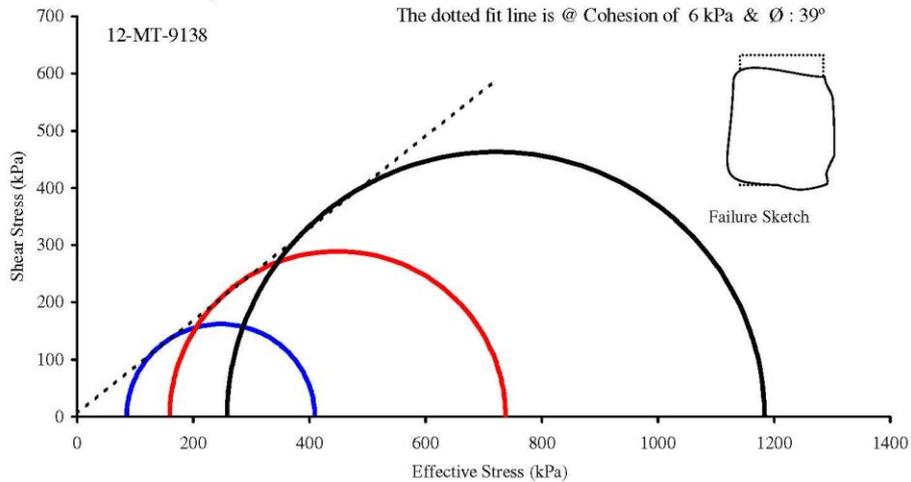
- According to SGS In-House Test Method # 5

Page 1 of 5

<b>CLIENT :</b> D E Cooper & Associates Pty Ltd		<b>JOB NO :</b> 12-01-2018
<b>PROJECT :</b> Solid waste 08-08-12		<b>LOCATION :</b>
<b>Sample Id :</b> Consolidated Isotropically Undrained, Multi-stage		<b>Lab No. :</b> 12-MT-9138
<b>Test Type :</b> Consolidated Isotropically Undrained, Multi-stage		<b>Date Tested :</b> 30/10-26/11/12
<b>Specimen Details :</b>		<b>Sample Description (Visual) :</b> reddish yellow clayey SILT ( tailing)
<b>Placement</b>	<b>Final</b>	<b>Saturation Stage Data</b>
Length/Diameter (ratio) : 1.94	-	Pore Pressure Coefficient, B : 0.96
Dry Density (t/m <sup>3</sup> ) : 1.279	1.371	
Moisture Content (%) : 33.1	37.2	

**Sampling Details :** 61mm Ø remoulded sample @ 96% of MDD & 100% of OMC

### MOHR CIRCLES - Composite Plot



### SHEAR STAGE DATA (Failure based on peak effective stress ratio)

Stage No	Strain Rate (mm/min)	$\epsilon_f$ (%)	$(\sigma'_1 / \sigma'_3)_f$ (ratio)	$\sigma_3$ (kPa)	$U_o$ (kPa)	$U_f$ (kPa)	$(\sigma'_1)_f$ (kPa)	$(\sigma'_1 - \sigma'_3)_f$ (kPa)
1	0.05	2.15	4.81	550	400	465	409	324
2	0.05	3.99	4.64	700	400	541	737	578
3	0.05	5.05	4.59	850	400	592	1184	926

Cohesion, C (kPa) : 6

Friction Angle,  $\phi$  (degrees) : 39

### CONSOLIDATION TEST DATA ( $\Delta\sigma'_3$ of 10 kPa used during initial saturation stage)

Stage No	$\Delta\sigma'_3$ (kPa)	$c_v$ (m <sup>2</sup> /year)	$M_v$ (m <sup>2</sup> /MN)	k (m/sec)	Drainage Condition
1	140	-	-	-	One End & Radial
2	150	-	-	-	One End & Radial
3	150	-	-	-	One End & Radial

Failure Mode : barrelling

Notes : Corrected area used for stress calculations  
Sample supplied by client

Authorised Signatory : Q Yazdani ( Q.Yazdani )

Date : 26/11/12

Certificate No.: 12-MT-9138 / S700-S719

5 Yelland Way, Bassendean WA 6054 Phone 1300 781 744 Fax (08) 9378 0199

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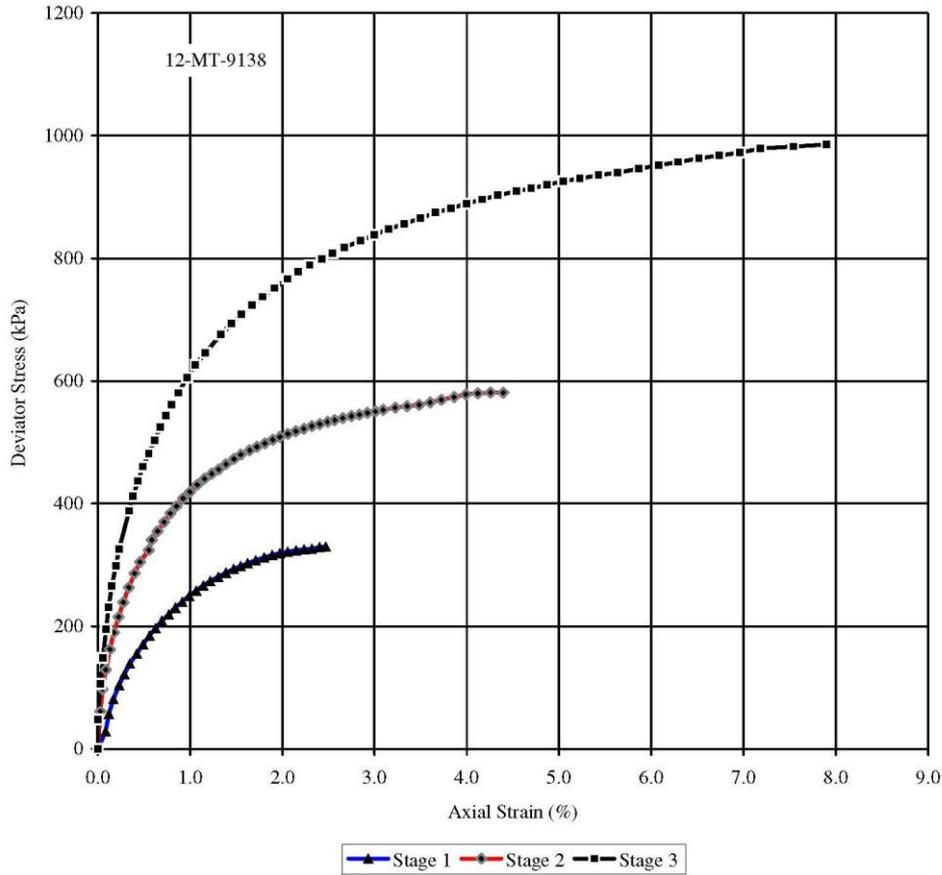
## TRIAXIAL SHEAR TEST REPORT CERTIFICATE

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<p><b>CLIENT :</b> D E Cooper &amp; Associates Pty Ltd</p> <p><b>PROJECT :</b></p> <p><b>Sample Id :</b> Solid waste 08-08-12</p> <p><b>Test Type :</b> Consolidated Isotropically Undrained, Multi-stage</p> <p><b>Specimen Details :</b></p> <table border="0" style="width: 100%;"> <tr> <td style="width: 30%;"></td> <td style="width: 30%; text-align: center;"><b>Placement</b></td> <td style="width: 30%; text-align: center;"><b>Final</b></td> </tr> <tr> <td>Length/Diameter (ratio) :</td> <td style="text-align: center;">1.94</td> <td style="text-align: center;">-</td> </tr> <tr> <td>Dry Density (t/m<sup>3</sup>) :</td> <td style="text-align: center;">1.279</td> <td style="text-align: center;">1.371</td> </tr> <tr> <td>Moisture Content (%) :</td> <td style="text-align: center;">33.1</td> <td style="text-align: center;">37.2</td> </tr> </table>		<b>Placement</b>	<b>Final</b>	Length/Diameter (ratio) :	1.94	-	Dry Density (t/m <sup>3</sup> ) :	1.279	1.371	Moisture Content (%) :	33.1	37.2	<p><b>JOB NO :</b> 12-01-2018</p> <p><b>LOCATION :</b></p> <p><b>Lab No. :</b> 12-MT-9138</p> <p><b>Date Tested :</b> 30/10-26/11/12</p> <p><b>Sample Description (Visual) :</b> reddish yellow clayey SILT ( tailing)</p> <p><b>Saturation Stage Data</b> -</p> <p>Pore Pressure Coefficient, B : 0.96</p>
	<b>Placement</b>	<b>Final</b>											
Length/Diameter (ratio) :	1.94	-											
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Moisture Content (%) :	33.1	37.2											

**Sampling Details :** 61mm Ø remoulded sample @ 96% of MDD & 100% of OMC

**Deviator Stress Vs Axial Strain**



Note : deviator stress =  $(\sigma_1 - \sigma_3)$

Authorised Signatory : Q Yazdani ( Q.Yazdari )      Date : 26/11/12  
 Certificate No.: 12-MT-9138 / S700-S719





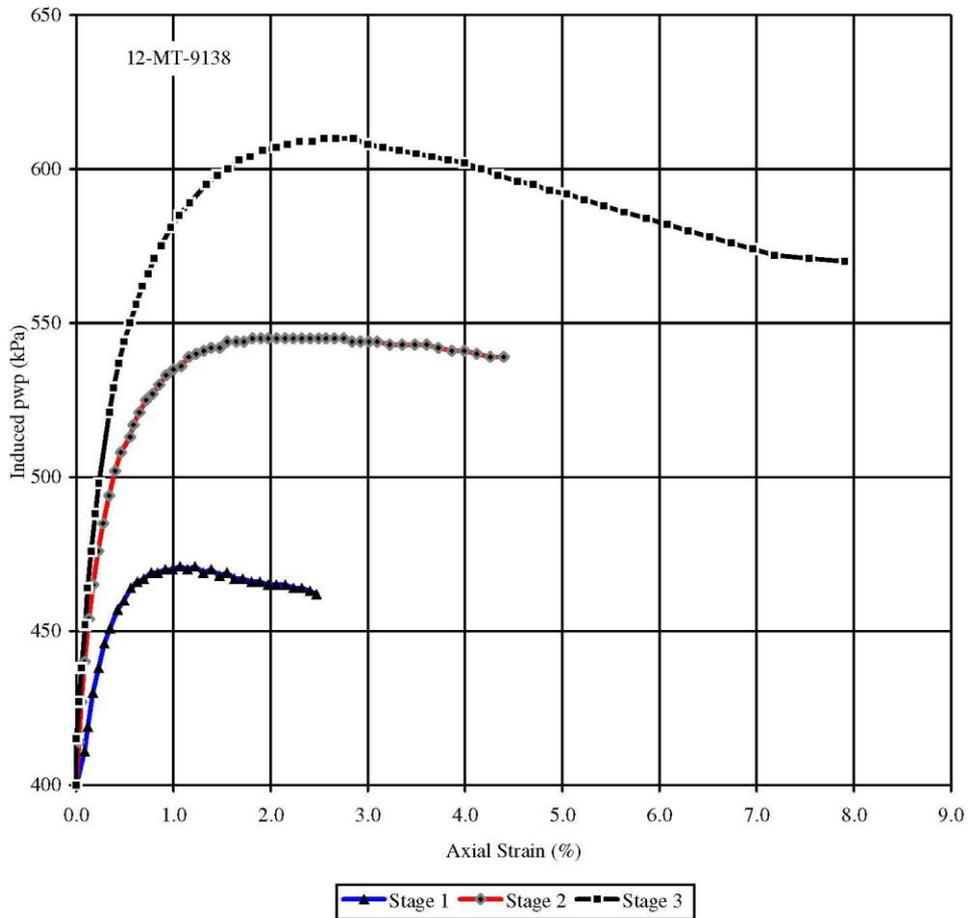
## TRIAxIAL SHEAR TEST REPORT CERTIFICATE

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Length/Diameter (ratio) :	1.94	-											
Dry Density (t/m <sup>3</sup> ) :	1.279	1.371											
Moisture Content (%) :	33.1	37.2											

**Sampling Details :** 61mm Ø remoulded sample @ 96% of MDD & 100% of OMC

**Induced Pore Water Pressure Vs Axial Strain**



Authorised Signatory : Q. Yazdani ( Q.Yazdari )      Date : 26/11/12

Certificate No.: 12-MT-9138 / S700-S719  
PF-(AU)-[IND(MTE)]-TE-S700-S719.PCE/A/01.01.2009



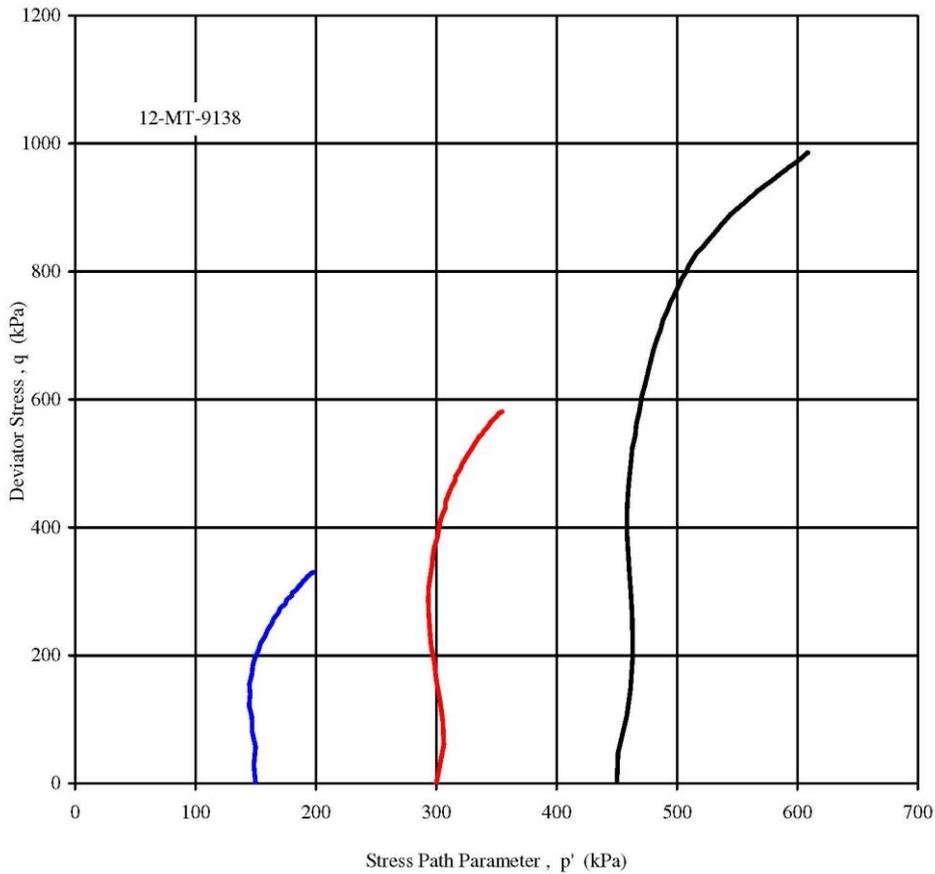


## TRIAxIAL SHEAR TEST REPORT CERTIFICATE

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<b>CLIENT :</b> D E Cooper & Associates Pty Ltd			<b>JOB NO :</b> 12-01-2018
<b>PROJECT :</b>			<b>LOCATION :</b>
<b>Sample Id :</b> Solid waste 08-08-12			<b>Lab No. :</b> 12-MT-9138
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**Effective Stress Path (Cambridge Method)**



Note :  $p' = (\sigma_1' + 2\sigma_3')/3$  &  $q' = q = (\sigma_1' - \sigma_3')$

Authorised Signatory : Q. Yazdani ( Q.Yazdari )    Date : 26/11/12  
 Certificate No.: 12-MT-9138 / S700-S719

PF-(AU)-[IND(MTE)]-TE-S700-S719.CCE/A/01.01.2009



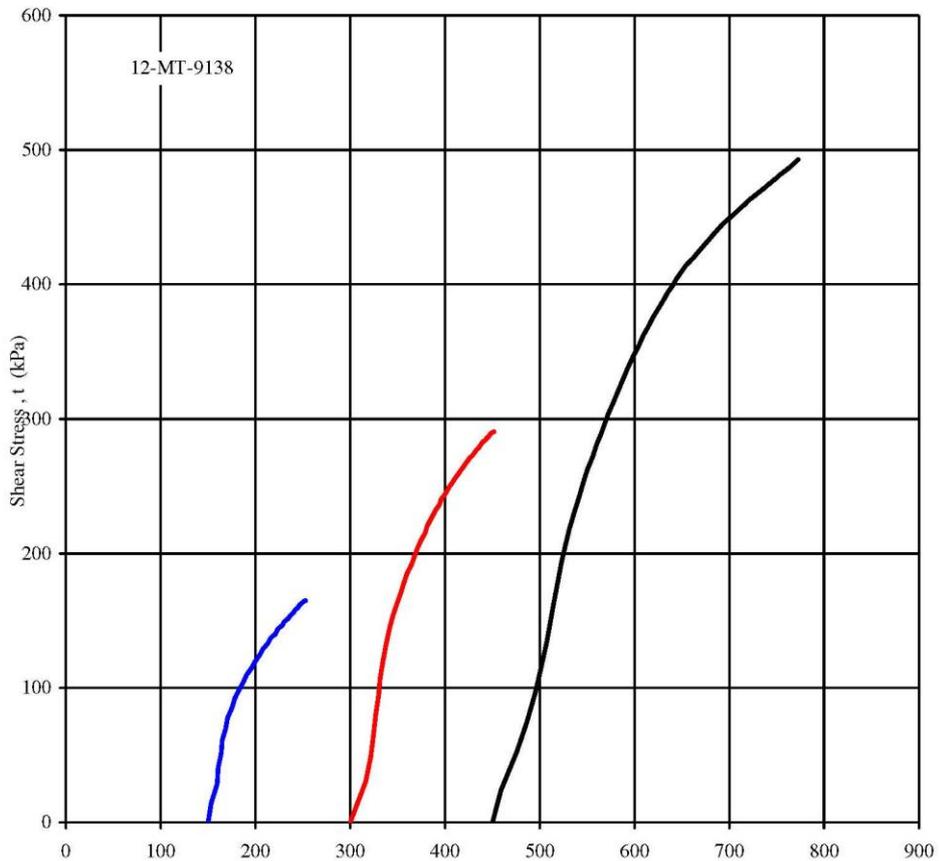


## TRIAXIAL SHEAR TEST REPORT CERTIFICATE

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<b>CLIENT :</b> D E Cooper & Associates Pty Ltd			<b>JOB NO :</b> 12-01-2018
<b>PROJECT :</b>			<b>LOCATION :</b>
<b>Sample Id :</b> Solid waste 08-08-12			<b>Lab No. :</b> 12-MT-9138
<b>Test Type :</b> Consolidated Isotropically Undrained, Multi-stage			<b>Date Tested :</b> 30/10-26/11/12
<b>Specimen Details :</b>	<b>Placement</b>	<b>Final</b>	<b>Sample Description (Visual) :</b>
Length/Diameter (ratio) :	1.94	-	reddish yellow clayey SILT ( tailing)
Dry Density (t/m <sup>3</sup> ) :	1.279	1.371	
Moisture Content (%) :	33.1	37.2	
			<b>Saturation Stage Data</b> -
			Pore Pressure Coefficient, B : 0.96
<b>Sampling Details :</b> 61mm Ø remoulded sample @ 96% of MDD & 100% of OMC			

**Effective Stress Path (M.I.T. Method)**



Note :  $s' = (\sigma'_1 + \sigma'_3)/2$  &  $t = (\sigma'_1 - \sigma'_3)/2$       Stress Path Parameter ,  $s'$  (kPa)

Authorised Signatory : Q Yazdani ( Q.Yazdari )

Date : 26/11/12

Certificate No.: 12-MT-9138 / S700-S719

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## TEST CERTIFICATE

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SGS Australia Pty Ltd  
 PO Box 486 Bassendean WA 6934  
 5 Yelland Way  
 Bassendean WA 6054

Client:	D E Cooper & Associates Pty Ltd	Client Job No:	
Order No:		Project:	
Tested Date:	26/10/2012	Location:	
SGS Job Number:	12-01-2018	Sample No:	12-MT-9138
Lab:	Bassendean	Sample ID:	Solid waste 08-08-12

### PERMEABILITY: FALLING HEAD

AS1289.6.7.2 Remoulded sample

MDD:	Std. Max Dry Density (t/m <sup>3</sup> ):
Max. Dry Density :	1.33 t/m <sup>3</sup>
Optimum Moisture Content	33.1 %
Dry Density	1.26 t/m <sup>3</sup>
Dry Density Ratio :	94.3 %
Moisture Content:	33.5 %
Moisture Ratio:	101.0 %
Surcharge (kPa):	0.0
Hydraulic Head:	1,585 mm
Hydraulic Gradient:	16
Sieve Size (mm):	4.75
Percentage Retained:	0
<b>COEFFICIENT OF PERMEABILITY</b>	
<b>m/sec at 20 ° C</b>	<b>5.0E-07</b>

Note: Sample supplied by client.

Approved Signatory:  (Ranjith.Fernando)

Date: 30/10/2012

Form No. PF-(AU)-[IND(MTE)]-TE-S800.LCER/B/01.04.2010  
 Client Address: 85A Evans Street Shenton Parl WA 6008

Site No.: 2411  
 Cert No.: 12-MT-9138-S800  
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